REPORT DESCRIPTION

TACCIMO - WaSSI Water Balance Report
Report Date: 4-2-2013
Location: Francis Marion National Forest (Santee)

HOW TO CITE INFORMATION IN THIS REPORT

The following sources should be directly cited when discussing or summarizing results in this report.

WaSSI Model:
Sun, G., P. Caldwell, A. Noormets, E. Cohen, S. McNulty, E. Treasure, J.-C. Domec, Q. Mu, J. Xiao, R. John, and J. Chen. 2011. Upscaling key ecosystem functions across the conterminous United States by a water-centric ecosystem model. Journal of Geophysical Research 116: G00J05.

PRISM Historic Climate:
Gibson, W.P., C. Daly, T. Kittel, D. Nychka, C. Johns, N. Rosenbloom, A. McNab, and G. Taylor. 2002. Development of a 103-year high-resolution climate data set for the conterminous United States. In: Proceedings, 13th AMS Conference on Applied Climatology, American Meteorological Society, Portland, OR, May 13-16, 181-183.

GCM Climate Projections :
Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor. 2007. The WCRP CMIP3 multi-model dataset: a new era in climate change research. Bulletin of the American Meteorological Society 88: 1383-1394.

This report was generated by the TACCIMO tool and may be acknowledged using the name and date listed above, along with the TACCIMO website (www.taccimo.sgcp.ncsu.edu).

BEST AVAILABLE SCIENTIFIC INFORMATION

The scientific information summarized within this report is drawn from two peer-reviewed sources, downscaled climate data and WaSSI ecosystem services model results. WaSSI is designed to provide broad-scale assessments using readily available data collected using consistent methodologies across broad regions. Model results at the local, HUC-8 watershed scale may vary from actual conditions, and users are cautioned to consider this uncertainty in interpreting results for their watershed of interest.

NEXT STEPS

Consult the TACCIMO climate report for a standardized approach for assessing uncertainty and establish a basis for confidence in model results. Present the information summarized in this report to specialists on your team and request feedback as it relates to specific resources or conditions of interest or concern. Consult with local experts and stakeholders to further evaluate the merit and implications of this information. Refer to the WaSSI model user guide for more information on model modules, inputs, outputs, and additional references. Peer-reviewed references are the best source for information on model assumptions and limitations.

REPORT STORAGE/ARCHIVAL

This report may be appropriate as an appendix to a specialized analysis or may be included in an administrative record.

TACCIMO – WaSSI WATER BALANCE REPORT

Draft: 4-2-2013

Report Contents

This report provides a summary of water balance projections for a specified area and time period. The variables available include precipitation, temperature, runoff, actual evapotranspiration, potential evapotranspiration, fraction of precipitation as evapotranspiration, and soil water storage. Actual evapotranspiration accounts for available soil moisture and landcover (Sun et al. 2011). Potential evapotranspiration is computed using the Hamon (1963) PET equation. Soil water storage is computed using the Sacramento Soil Moisture Accounting Model (SAC-SMA; Burnash et al. 1973, Burnash 1995, Koren et al. 2003).

Variable		Units		Values	
Temperature	X	Metric (°C, mm)	X	Absolute	X
Precipitation	X	English (°F, in)		Change (%)	
Runoff	X				
Actual Evapotranspiration (AET)	X				
Potential Evapotranspiration (PET)					
Fraction of Precipitation as Evapotranspiration					
Soil Water Storage					

Impacts of future climate change are included in the water balance summaries. Future climate projections were scaled to the 8-digit watershed scale from Meehl et al. (2007). At this time, there are three global climate models available. IPCC SRES emission scenarios range from low to high. Raupach et al. (2007) states that emissions since 2000 were closest to the A2 scenario trajectory, with the rate of increase exceeding the highest of all SRES scenarios, A1FI.

Climate Model (GCM)		SRES Emission Scenarios	
CGCM3		B1 (low)	
CM2	X	A1B (middle)	
HadCM3		A2 (high)	X

Water balance summaries are available in table, chart, and map form and can be generated for annual, seasonal, or monthly time steps. There are two historic time periods available, both spanning 1961-1990. The observed historic data are derived from PRISM (Gibson et al. 2002), and the predicted historic data are derived from the selected climate model. The other time periods span 20 years each and are all derived from the selected climate model.

Time Step	Table	Chart	Map	Time Periods	Table	Chart	Map
Annual	X	X	X	1961-1990 (PRISM observed historic)		X	X
Seasonal				1961-1990 (GCM predicted historic)	X	X	
Monthly				2010-2029	X	X	X
				2030-2049	X	X	X
				2050-2069			
				2070-2089			

At this time, water balance summaries are only available for the 8-digit HUC watershed scale.

Geographic Scale		
8-Digit HUC	X	3050112 (Santee)

INTRODUCTION

The TACCIMO WaSSI report gives an overview of potential climate change impacts on hydrology and ecosystem productivity, as predicted by the WaSSI ecosystem services model. The TACCIMO climate report provides additional useful context for understanding climate variables and should be reviewed in conjunction with this report, for the same location and time period(s).Water availability and carbon sequestration are closely related ecosystem services that are influenced by human and environmental factors such as climate change, land cover, and water withdrawals. To evaluate the balances and tradeoffs between these ecosystem services, scientists from the USDA Forest Service Eastern Forest Environmental Threat Assessment Center (EFETAC) have developed a web-based planning tool known as the WaSSI Ecosystem Services Model. Climate researchers project temperature increases and precipitation variability across the United States during the next 100 years.

Climate and Hydrology Overview

This section highlights key results for HUC 03050112 (Santee) that are also represented in additional detail, including maps and charts, in subsequent sections of this report. The results presented in this report are based on the PRISM (Gibson et al. 2002) historic climate dataset and the CM2 A2 general circulation model (GCM; Meehl et al. 2007).

Table 1—Summary of mean annual temperature, precipitation, runoff, and AET variables, averaged over the historic and future time periods

	Temperature		**Precipitation**		**Runoff**		**AET**	
	PRISM	CM2 A2	PRISM	CM2 A2	PRISM	CM2 A2	PRISM	CM2 A2
	--- C ---		*--- mm ---*		*--- mm ---*		*--- mm ---*	
1961-1990	17.6	17.7	1272	1297	369	385	905	915
2010-2029	-	18.5	-	1466	-	499	-	966
2030-2049	-	19.1	-	1387	-	437	-	958

Table 2—Summary of change in mean annual temperature, precipitation, runoff, and AET variables from the historic baseline

	Temperature Change	**Precipitation Change**		**Runoff Change**		**AET Change**	
	Absolute	Absolute	Percent	Absolute	Percent	Absolute	Percent
	--- C ---	*--- mm ---*	*--- % ---*	*--- mm ---*	*--- % ---*	*--- mm ---*	*--- % ----*
2010-2029	0.8	169	13.0	114	29.6	51	5.6
2030-2049	1.4	90	6.9	52	11.9	43	4.7

Table 3—Summary ratios between runoff/ precipitation and AET/ precipitation for historic and future time periods

	Runoff / Precipitation		**AET / Precipitation**	
	PRISM	CM2 A2	PRISM	CM2 A2
	--- % ---		--- % ---	
1961-1990	29	30	71	70
2010-2029	-	34	-	66
2030-2049	-	31	-	69

HISTORIC CLIMATE AND HYDROLOGY

This section summarizes basic measures of future projected climate and the impacts to hydrology.

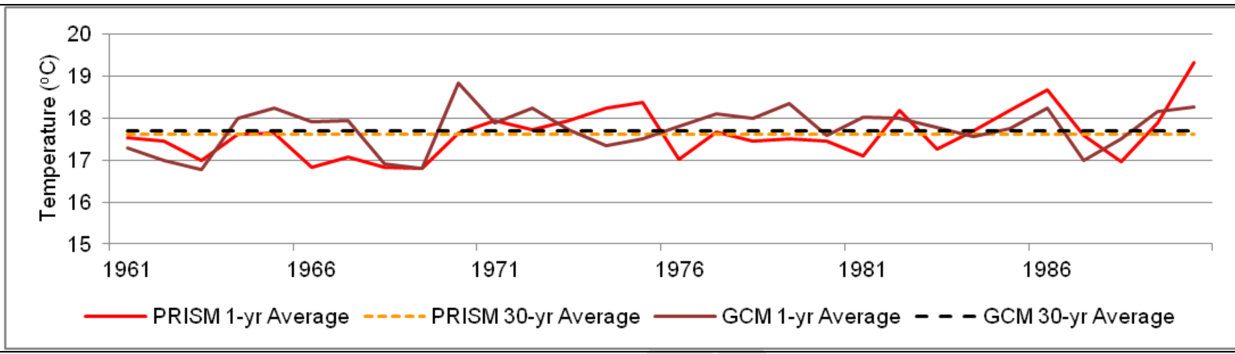

Figure 1— Historic average annual temperature with long-term average for observed (PRISM) and predicted (GCM) models

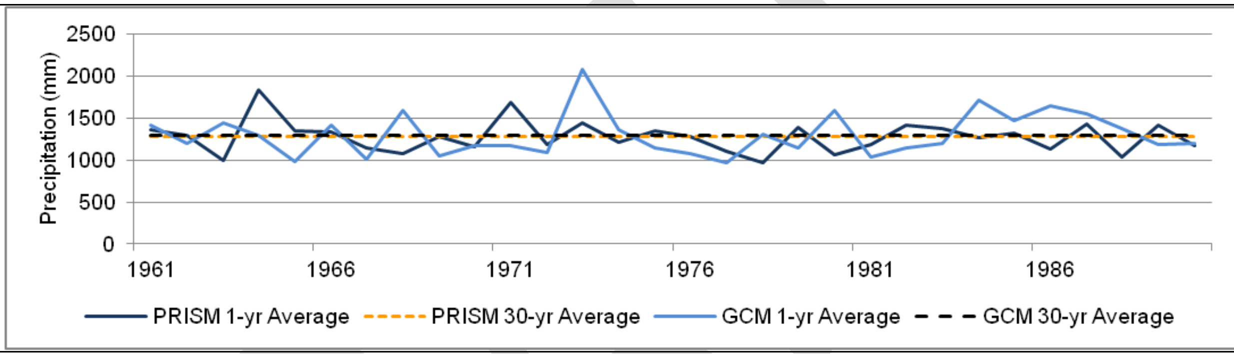

Figure 2— Historic average annual precipitation with long-term average for observed (PRISM) and predicted (GCM) models

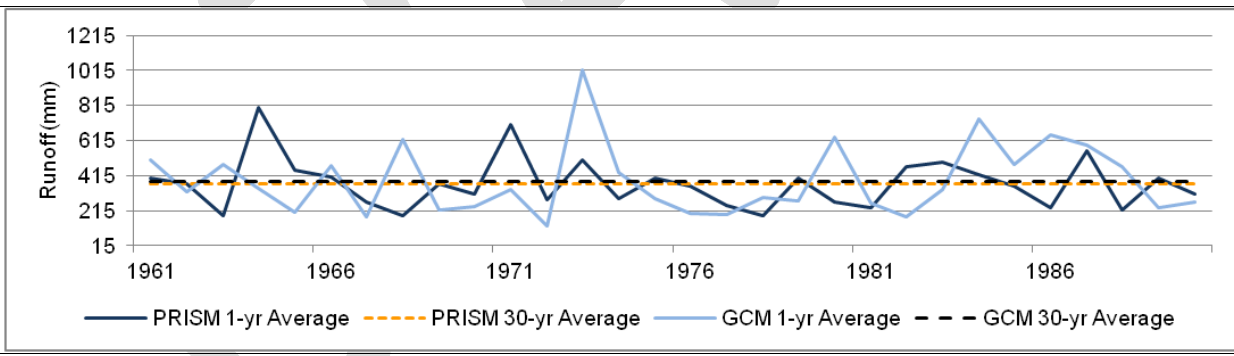

Figure 3— Historic average annual runoff with long-term average for observed (PRISM) and predicted (GCM) models

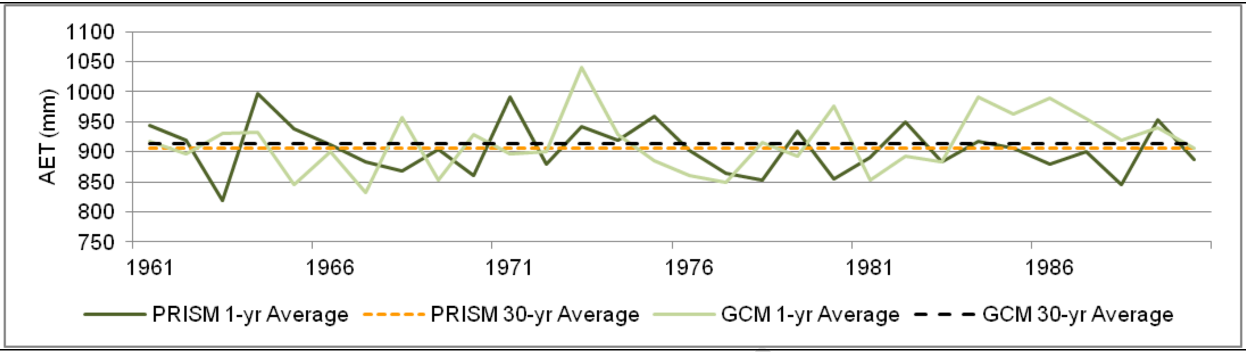

Figure 4—Maps of historic average AET and time series graph displaying values for each year in the same time period

FUTURE CLIMATE AND HYDROLOGY

This section summarizes basic measures of future projected climate and the impacts to hydrology.

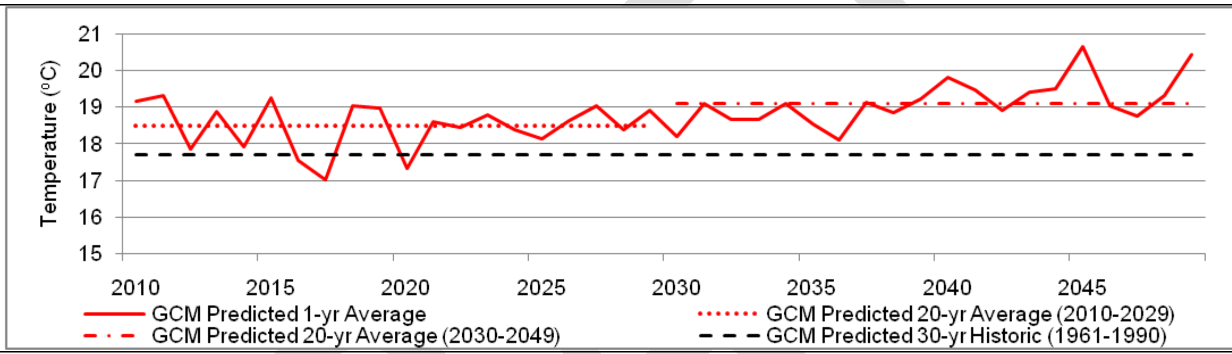

Figure 5—Future average annual temperature with long-term average from the predicted (GCM) model

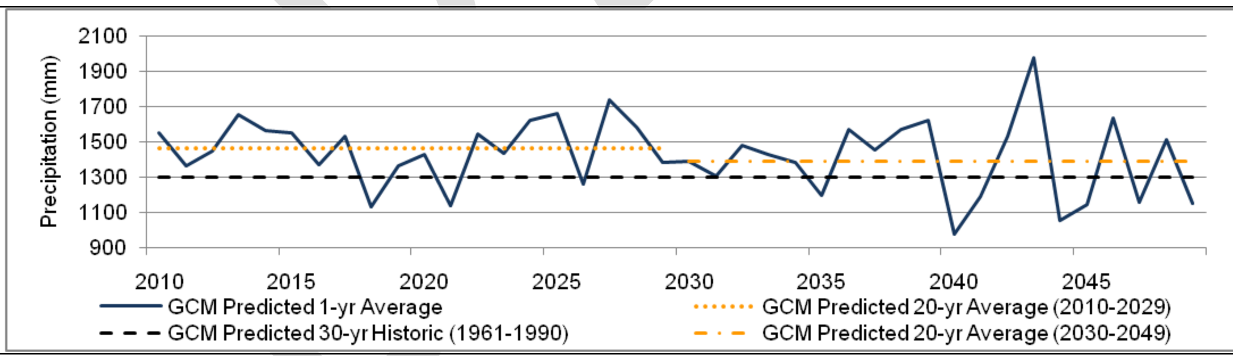

Figure 6— Future average annual precipitation with long-term average from the predicted (GCM) model

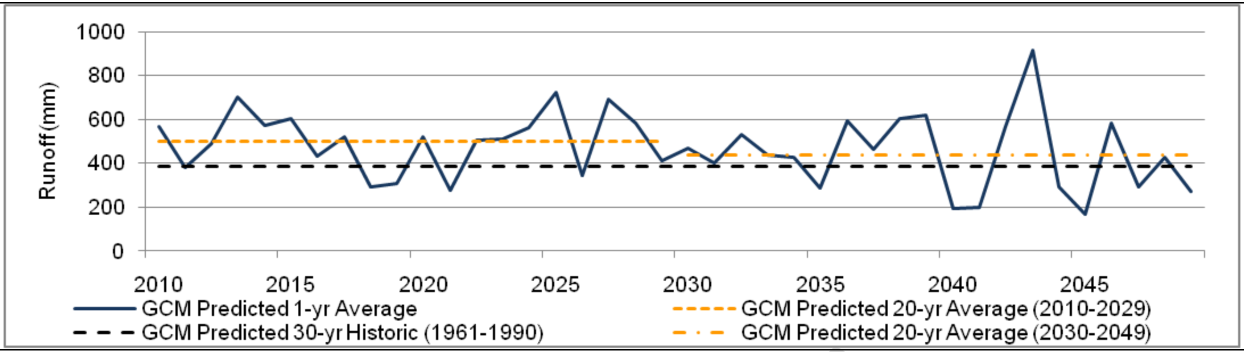

Figure 7— Future average annual runoff with long-term average predicted by the WaSSI model

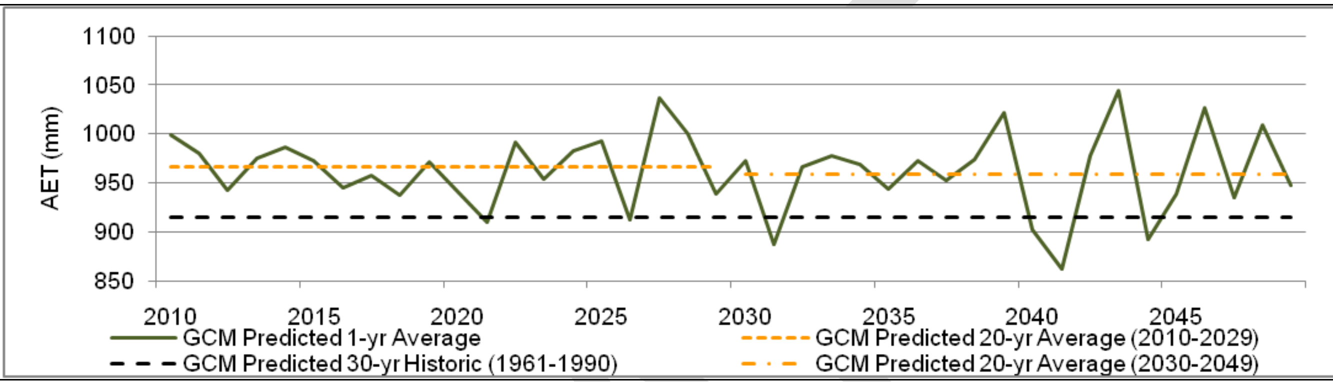

Figure 8— Future average annual AET with long-term average predicted by the WaSSI model

INTERPRETIVE GUIDANCE

Models and Scenarios

WaSSI is an integrated monthly water balance and flow routing model that simulates the full hydrologic cycle for ten land cover classes for 8-digit Hydrologic Unit Code (HUC) watersheds across the conterminous US. WaSSI's water balance module computes ecosystem water use, evapotranspiration (ET), and the water yield from each watershed. Water yield is sometimes referred to as runoff and can be thought of as the amount of streamflow at the outlet of each watershed due to hydrologic processes in each watershed in isolation without any flow contribution from upstream watersheds. For more specifics on the WaSSI model, consult the resources listed at the end of this report. Users are encouraged to read the peer-reviewed WaSSI documentation for further information regarding model assumptions and limitations:

Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J.A. Moore Myers. 2012. Impacts of impervious cover, water withdrawals, and climate change on river flows in the conterminous US. Hydrol. Earth Syst. Sci. 16: 2839-2857. doi:10.5194/hess-16-2839-2012.

Caldwell, P.V., G. Sun, S.G. McNulty, E.C. Cohen, and J.A. Moore Myers. 2011. Modeling Impacts of Environmental Change on Ecosystem Services across the Conterminous United States. In: Medley, C.N., G. Patterson, and M.J. Parker, (eds). Observing, studying, and managing for change: Proceedings of the Fourth Interagency Conference on Research in the Watersheds. U.S. Geological Survey Scientific Investigations Report 2011:5169. 202 p.

Sun, G., P. Caldwell, A. Noormets, E. Cohen, S. McNulty, E. Treasure, J.-C. Domec, Q. Mu, J. Xiao, R. John, and J. Chen. 2011. Upscaling key ecosystem functions across the conterminous United States by a water-centric ecosystem model. Journal of Geophysical Research 116: G00J05.

Sun G., K. Alstad, J. Chen, S. Chen, C. R. Ford, G. Lin, N. Lu, S. G. McNulty, A. Noormets, J.M. Vose, B. Wilske, M. Zeppel, Y. Zhang, and Z. Zhang. 2011. A general predictive model for estimating monthly ecosystem evapotranspiration. Ecohydrology 4(2):245-255.

Sun, G., S.G. McNulty, J.A. Moore Myers, and E.C. Cohen. 2008. Impacts of Multiple Stresses on Water Demand and Supply across the Southeastern United States. Journal of American Water Resources Association 44(6):1441-1457.

Uncertainty and Model Evaluation

Climate datasets, both historic and projected, are subject to natural and analysis-based (e.g., downscaling) uncertainty. Climate projections at finer geographic and/or temporal scales come with greater uncertainty; thus, it is prudent to evaluate indications of less or more uncertainty in the model results. By averaging across temporal periods we have attempted to reduce uncertainty stemming from natural variability. Consult the TACCIMO climate report for a standardized approach for assessing uncertainty and establish a basis for confidence in model results.

WaSSI predictions for water balance and runoff were validated using monthly, observed runoff measurements between 1961 and 2007 at the outlets of ten representative watersheds across the US. This validation demonstrated the WaSSI model's ability to capture the spatial and temporal variability of the natural water balance, such as evapotranspiration, and runoff processes. Across the ten USGS Hydro-Climatic Data Network (HCDN) gauge sites, the WaSSI model performed well in estimating annual and monthly runoff patterns. Correlations between annual and monthly observed and predicted runoff were all significant ($P < 0.01$), indicating that the model successfully captured the temporal variability in monthly runoff at these sites. Bias in mean annual runoff prediction was within 20% at most sites, and errors in predicted runoff may be attributed to uncertainty in input data such as climate and soil properties, as well as uncertainty in the simplified representation of the physical processes that govern runoff magnitude and timing.

Please include the following acknowledgement when you produce documents based on TACCIMO datasets: "We acknowledge TACCIMO for making the downscaled climate projections, derivative models, and context layers publicly available. Support for these products was provided by the USDA Forest Service Threat Centers, Region 8, and Region 5."

METADATA AND DISCLAIMER

Historic climate data were derived from data provided by PRISM Modeling Group at Oregon State University. Parameter-elevation Regressions on Independent Slopes Model (PRISM) data have spatial resolution of 4 km, spatial extent of the conterminous US, temporal resolution of month, and temporal extent of 1895-1997. Data are described in detail in W.P. Gibson, C. Daly, T. Kittel, D. Nychka, C. Johns, N. Rosenbloom, A. McNab, and G. Taylor. 2002. Development of a 103-year high-resolution climate data set for the conterminous United States. In: Proceedings, 13th AMS Conference on Applied Climatology, American Meteorological Society, Portland, OR, May 13-16, 181-183. Data are available at http://www.prism.oregonstate.edu/products/.

Climate projections were derived from data provided by the World Climate Research Programme's Coupled Model Intercomparison Project Phase 3 (CMIP3) dataset. These downscaled data have spatial resolution of 12 km, spatial extent of the conterminous US, temporal resolution of month, and temporal extent of 2001-2099. Data are described in detail in G.A. Meehl, C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor. 2007. The WCRP CMIP3 multi-model dataset: a new era in climate change research. Bulletin of the American Meteorological Society 88: 1383-1394. Data are available at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html. For additional metadata, please see the Metadata - Overview and Metadata - Details links on the TACCIMO GIS Viewer.

This geospatial information was prepared by the USDA Forest Service. These data were developed from sources of differing accuracy, based on modeling or interpretation, accurate only at certain scales, or incomplete while being created or revised. The Forest Service cannot assure the accuracy, completeness, reliability, or suitability of this information for any particular purpose. Using geospatial data for purposes other than those for which they were created may yield inaccurate or misleading results. The Forest Service is not liable for any activity involving this information with respect to losses or damages. In the future, TACCIMO may add more GCMs, derivative models, and context layers. Please continue to check the GIS Viewer for additional datasets (http://www.taccimogis.sgcp.ncsu.edu/TACCIMO/GIS/taccimo_gis.html).

References

Burnash, R.J.C., R.L. Ferral, and R.A. McGuire. 1973. A generalized streamflow simulation system - conceptual modeling for digital computers. Technical Report, Joint Federal and State River Forecast Center US National Weather Service and California Department of Water Resources. Sacramento, California. 204 p.

Burnash, R.J.C. 1995. The NWS river forecast system - catchment modelling. In: V.P. Singh (ed). Computer models of watershed hydrology. Water Resources Publications. Littleton, Colorado. pp. 311-366.

Gibson, W.P., C. Daly, T. Kittel, D. Nychka, C. Johns, N. Rosenbloom, A. McNab, and G. Taylor. 2002. Development of a 103-year high-resolution climate data set for the conterminous United States. In: Proceedings, 13th AMS Conference on Applied Climatology, American Meteorological Society, Portland, OR, May 13-16, 181-183.

Hamon, W.R. 1963. Computation of direct runoff amounts from storm rainfall. Int. Assoc. Sci. Hydrol. Pub. 63: 52–62.

IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. SolomonD. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Koren, V.M. Smith, and Q. Duan. 2003. Use of a priori parameter estimates in the derivation of spatially consistent parameter sets of rainfall-runoff models. In: Q. Duan, S. Sorooshian, H. Gupta, H. Rosseau, and H. Turcotte (eds). Calibration of Watershed Models Water Science and Applications, vol. 6. AGU. Washington, DC. pp. 239-254.

Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor. 2007. The WCRP CMIP3 multi-model dataset: a new era in climate change research. Bulletin of the American Meteorological Society 88: 1383-1394.

Nakicenovic, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, et al. 2000. Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. 599 pp. Available online at: http://www.grida.no/climate/ipcc/emission/index.htm.

Raupauch, M.R., G. Marland, P. Ciais, C. Le Quéré, J.G. Canadell, et al. 2007. Global and regional drivers of accelerating CO_2 emissions. PNAS 104(24): 10288-10293. doi:10.1073/pnas.0700609104.

Sun, G., P. Caldwell, A. Noormets, E. Cohen, S. McNulty, E. Treasure, J.-C. Domec, Q. Mu, J. Xiao, R. John, and J. Chen. 2011. Upscaling key ecosystem functions across the conterminous United States by a water-centric ecosystem model. Journal of Geophysical Research 116: G00J05.